a8b
TA
479
S7
F54
1923

FIRTH-STERLING

S-LESS

STAINLESS STEEL

FIRTH-STERLING

S-LESS

STAINLESS STEEL

FIRTH-STERLING STEEL COMPANY

General Office and Works:

McKeesport, Pa.

New York Boston Hartford Philadelphia
Chicago Cleveland Detroit Los Angeles
San Francisco

Price $1.00 Net

CONS
TA
479
S7
F54
1923

Copyright, 1923 by
FIRTH-STERLING STEEL COMPANY
McKEESPORT, PA.

ENGRAVED AND PRINTED BY
THOS B BROOKS, INC.
NEW YORK

"Th' invention all admir'd, and each, how he
To be th' inventor miss'd; so easy it seem'd,
Once found, which yet unfound most would have
thought
Impossible."

JOHN MILTON
[B. 1608]

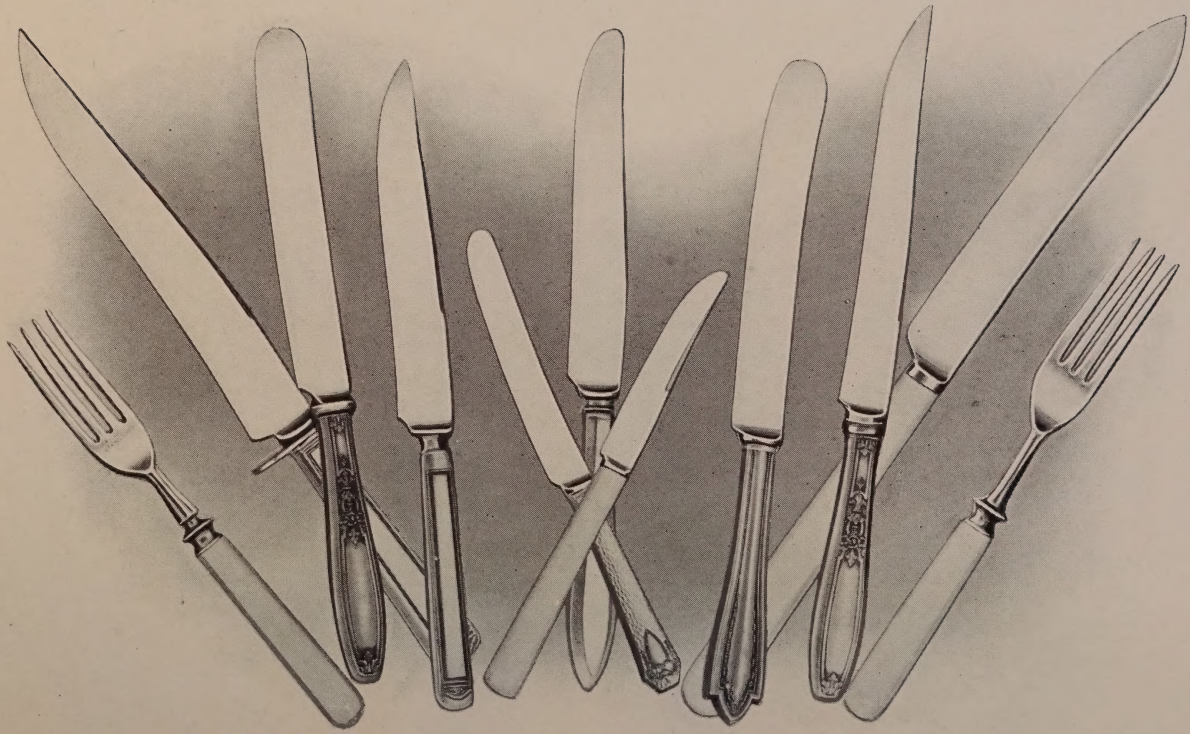


Table of Contents

Preface - - - - - 7

History - - - - - 9

Applications - - - - 11

Types of Stainless Steel - - 13

Heat Treatment and Working - 15

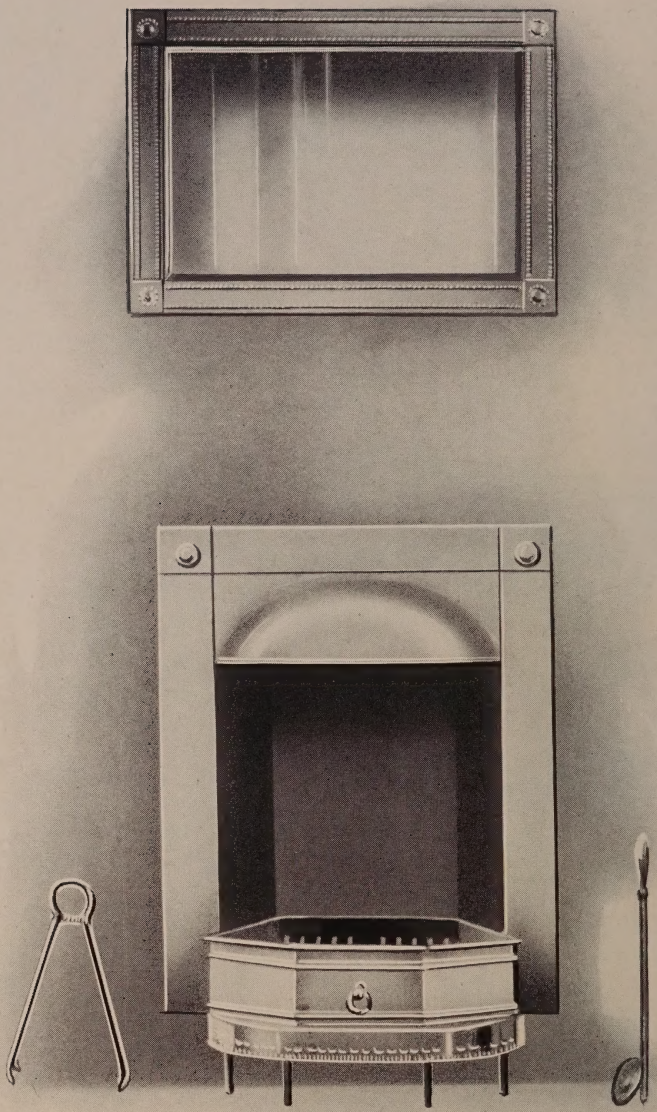
Chemical Analysis - - - 25

Physical Properties - - - 27

Resistance to Various Agencies of Rust, Stain and Corrosion - 41

Terms of Warranty - - - 55

Index - - - - - 57



PREFACE

THIS book has been prepared with the object of bringing before those interested in Stainless Steel such data as may save the trouble and expense of conducting experiments in the fields where experience has shown that it has, or has not, been found suitable. The information is based upon experiments made in our laboratory; in the laboratory of the Firths in Sheffield, England; and upon reports from customers who are using the material.

Special acknowledgment is due Messrs. Thos. Firth & Sons, Ltd., of Sheffield, our own Metallurgical Staff, at McKeesport, Pa., and the many customers who have coöperated.

Although Stainless Steel is now used for a great variety of purposes new applications are being found from day to day; consequently any treatise on it at this time is of a preliminary nature. Later editions must necessarily follow.

Firth-Sterling Steel Company

July 1st, 1923.

HISTORY

STAINLESS STEEL has marked an epoch in the manufacture of steel secondary only in importance to High Speed Steel at the beginning of the present century. Although its development was somewhat retarded during the late War, its worth has now been fully proven under actual service conditions and it has established itself as a valuable commercial product.

The value of high percentages of Chromium in imparting special properties to iron and steel has been known for many years. As early as 1872 the effect of Chromium in producing non-corrosive properties in steel was vaguely described by two Englishmen who made an application for a patent which was never granted. There were no important developments until about 1912 when Mr. Harry Brearley, in the laboratory of Thos. Firth & Sons, Ltd., Sheffield, England, discovered the combination of alloys, and developed the necessary manufacturing details, to produce a steel which would neither rust, stain nor tarnish when subject to the ordinary agencies of rust, stain and corrosion.

At the time that Mr. Harry Brearley was developing Stainless Steel in England, Mr. Elwood Haynes was working independently in the United States on the same problem. Both were granted United States patents. These and other patents have since been acquired by the American Stainless Steel Company. (The

American Stainless Steel Company owns the Stainless Steel Patents, but does not manufacture or sell steel.)

FIRTH-STERLING [S-LESS] STAINLESS STEEL

and

FIRTH-STERLING [S-LESS] STAINLESS IRON

are manufactured under a license from this company.

The work by Thos. Firth & Sons, Ltd., Sheffield, England, and the Firth-Sterling Steel Company, McKeesport, Pa., during the years since 1912, has brought the steel to its present state of perfection. During the War its use was restricted to war purposes, many tons of it going into valves for aeroplane motors. Since the War its development has been vigorously carried on, and engineers have recognized its value in many directions. At about the same time that Stainless Steel was discovered in the Sheffield Works, another type of stainless material, "Stainless Iron," was made in the laboratory of the Firth-Sterling Steel Company at McKeesport. Its development was also delayed by the War.

Applications and Possibilities

There is a wide field for rustless, stainless steel or iron because, since the earliest use of steel and iron, rust and corrosion have been their greatest enemies. These are being overcome. Cutlery was first to take any considerable tonnage of Stainless Steel, but Stainless Steel and Stainless Iron have been used with success for a variety of purposes including:

Aeroplane Parts
Air Compressor Valves
Automobile Parts and Fittings
Artificial Limb Fittings
Balances, Knife Edges, Beams, etc.
Ball Bearings
Bicycle Parts
Bits, etc. (Horses)
Bolts, Nuts, etc.
Bottling Machinery
Bread-making Machinery
Buckles: Shoe, Harness, etc.
Builders' Tools
Butchers' Rails, Hooks, etc.
Carburetor Needles, Jets, Screws, etc.
Clock Parts
Cold Storage Equipment
Cooking Utensils
Cutlery
Dairy Apparatus
Dental Instruments
Dies
Drawing Instruments
Electrical Appliances
Engines: Aero, Gas, Oil, etc.
Fishing Tackle
Forks
Gauges
Golf Club Heads
Gun Parts

House Fittings
Instruments, Musical
Keys
Knives
Laboratory Fittings
Locks
Machinery Parts
Micrometer Frames
Motion Picture Machinery
Motor Cycle Parts
Moulds
Needles
Ornamental Metal Work
Paper and Pulp Machinery Parts
Periscope Parts
Phonograph Parts
Pump Rods and Parts
Railroad Equipment
Refrigerator Parts
Roller Bearings
Saddlery Hardware
Scale Parts
Sewing Machine Parts
Soap - manufacturing Machinery
Soda Fountain Parts
Surgical Instruments
Tools
Turbine Blading, Nozzles, etc.
Washing Machine Parts
Water Meter Parts
Weighing Machine Parts
Yacht Fittings

Types of Firth-Sterling [S-LESS] Stainless Steel

Stainless Steel is supplied in three types, viz:

1. [S-LESS] Steel Annealed
2. [S-LESS] Steel Particularly Annealed
3. [S-LESS] Iron

[S-LESS] STEEL ANNEALED is a material requiring heat treatment, and proper finishing, to bring out its rustless and stainless qualities. The same heat treatment has the effect of producing maximum strength.

The tensile strength of [S-LESS] Steel, heat treated, is approximately 110 tons—See Physical Properties, page 27.

[S-LESS] STEEL PARTICULARLY ANNEALED: As stated above this steel in the regularly annealed condition requires heat treatment to make it stainless but we have a method of giving the steel what we call a "Particular Annealing" which produces machinable steel that is stainless without further heat treatment. It is necessary, however, to remove the surface of the particularly annealed steel the same as the regularly annealed steel but this operation is considerably more difficult.

The harder the steel, the more stainless it is; therefore, our aim is to make the Particularly Annealed Steel just as hard as possible and still have it machinable.

S-LESS IRON has the general characteristics of wrought iron in that it is soft in the manufactured state and requires no annealing. Its physical properties and stainlessness can be improved by heat treating, but it remains machinable. It is exceedingly ductile and can be cold worked like a mild steel. The tensile strength of S-LESS Iron is thirty to forty tons which may be increased somewhat by heating to about 1900° F. and air cooling or quenching in oil. In the natural state S-LESS Iron machines about the same as ordinary bar iron. S-LESS Iron shows good stainless properties in the forged condition, but the oxidized surface must be removed.

CAUTION!

Any trace of oxide in

S-LESS Stainless Steel Annealed
S-LESS Stainless Steel Particularly Annealed
S-LESS Stainless Iron

causes a seat for electrolytic action which invariably results in corrosion. *This is a matter of vital importance.*

Firth-Sterling [S-LESS] Stainless Steel Heat Treatment

*Forging**

[S-LESS] Steel is more difficult to forge than regular tool steel. In this respect it resembles High Speed Steel. [S-LESS] Steel does not absorb heat readily, hence it is necessary to soak it at a low temperature, in the vicinity of 1300° F., for a long period of time, as a preliminary measure to insure softness and uniform heating for forging. In general it should be left in the furnace two to three times as long as ordinary steels of the same size and shape. Between the temperatures of 1700° F. and 2000° F., [S-LESS] Steel can be forged without danger of rupture, but below 1700° F., it forges with difficulty and if forcibly deformed at this temperature by heavy blows, excessive strains and breakage will result. Frequent reheating is, therefore, recommended.

[S-LESS] Steel is an air-hardening steel and if allowed to cool in the air from its forging heat becomes hard. Just how hard the steel will be, depends upon the temperature to which it has been previously heated and also upon the cross-section of the finished product. The hardness may vary to a considerable extent. For

* For forging [S-LESS] Iron see Page 19.

instance, it may correspond to a Brinell number as high as 550 if the initial heating temperature was between 1700° F. and 2000° F. If an excessively high forging temperature is used, such as one in excess of 2200° F., the steel is burned and the resultant forged mass is soft, but brittle, and shows a Brinell in the vicinity of 300. No general use therefore should be made of the resultant hardness of air-cooled forgings. Attempts to hammer knife blades and thin sections until they are black, with the object of making them hard and resilient, should be discouraged; results obtained are not only very unreliable as regards uniform hardness, but the material is in a highly stressed condition and liable to break. Forgings made in this manner will rust or corrode.

Normalizing and Annealing

The critical point of S-LESS Steel is in the vicinity of 1530° F. As with any other air-hardening steels, normalizing is impossible. The range of hardening and that of normalizing are almost identical, hence the failure of the process. Strains incidental to forging and machining can be relieved by holding the steel at a temperature of about 1300° F. for a short time, and then allowing it to cool in the air.

To anneal S-LESS Steel to get the best machining properties, it should be held for some time at a temperature of from 1350° F. to 1400° F. and allowed to cool either in the furnace or in the open air.

Hardening

The proper hardening range for [S-LESS] Steel is from 1750° F. to 1900° F., depending upon size and hardness desired. The steel being an air-hardening one, thin sections or intricate shapes which are likely to warp or break if quenched, can be hardened by air cooling from the higher temperatures of the range, but the work will not be quite so hard as if it had been cooled in oil or water. The steel shows its maximum hardness when quenched in water or brine, but for all general purposes, quenching in oil at 1800° F. to 1850° F. will give the best results. The higher the quenching temperature, within reasonable limits, the better the general results will be. Although [S-LESS] Steel hardens at a comparatively high temperature, its hardening heat must not be confused with that of High Speed Steel.

Considerable care should be exercised in heating [S-LESS] Steel for hardening as it absorbs heat very slowly. In heating for hardening it should be held in the furnace about two to three times as long as ordinary steels to reach a uniform temperature. Wherever practicable, [S-LESS] Steel should be given a thorough preheating at a temperature of about 1300°F. before being placed in the full hardening heat. This is especially applicable to heavy sections.

Tempering

The strains set up in hardening should be relieved by drawing the temper. The extent to which the steel is drawn is limited by the purpose intended. For instance where a piece drawn to 575° F.—950° F. will show a tensile strength of approximately 100 tons and a Brinell hardness exceeding 500, increasing the drawing temperature to 1350° F. reduces the tensile strength to approximately 50 tons and the Brinell hardness to approximately 300. The effect of various heats is illustrated on pages 29, 30, 33 and 34.

The heating curves illustrated in the charts on pages 33 and 34 were taken from the Bureau of Standards Scientific Paper No. 426, pages 512 and 513. Firth-Sterling S-LESS Stainless Steel was used in these tests.

Discoloration at High Temperatures: The colors which appear on polished steel as it is heated are frequently called "temper colors" and are due to very thin films of oxidized metal. Firth-Sterling S-LESS Stainless Steel resists oxidation and more heat is required to produce a given color than in ordinary tool steels, as is illustrated by the table on the opposite page.

Temper Colors

COLOR	APPEARS ON TOOL STEEL		APPEARS ON STAINLESS STEEL	
	Deg. C.	Deg. F.	Deg. C.	Deg. F.
Pale Straw	220	428	250	482
Dark Straw	230	446	300	572
Dark Straw—brownish	240	464	350	662
Brownish—purple	260	500	400	752
Reddish—purple brown	270	518	450	842
Full purple	290	554	500	932
Purple Blue—violet	300	572	550	1022
Dark Blue	310	590	600	1112
Greenish Blue	320	608	650	1202
Steel Gray	340	644	700	1292
Brownish Gray	360	680	750	1382

The above colors are only approximate and vary in different lights and because of surface conditions, also by reason of the conditions under which the heating has been done.

Forging S-LESS *Iron*

In forging S-LESS Iron, as in forging S-LESS Steel, it is essential that the Iron be allowed to soak at a low temperature for some time to insure uniform heating. It is also important that the maximum forging heat be kept below 1900° F. At higher temperatures the Iron tends to stiffen or harden slightly and is less machinable. To soften from this condition cool slowly from a temperature of approximately 1400° F.

Welding

S-LESS Steel and S-LESS Iron can be successfully welded by the electrical contact or fusion method. Both of these processes permit of its union to soft steel. It must be understood, however, that in electric welding, the temperature at the point of contact is raised very high and as a result the metal will be hard, with a tendency toward brittleness. Where possible, welded work should be annealed before further fabrication or treatment. The acetylene torch has very little effect upon this steel. It cuts it only with the greatest difficulty. It apparently cannot be satisfactorily welded with the ordinary methods in a smith's forge.

Brazing and Soldering

S-LESS Steel and S-LESS Iron can be soldered but, due to certain difficulties presented, the process of brazing is preferred. It is possible to successfully braze the steel if proper precautions are taken as to composition of brazing material, kind of flux, and the temperature of the work. A brass brazing alloy, composed of equal parts of copper and zinc is recommended. The working temperature is considerably above that customary for such work, being in the vicinity of 1600° F., which is well above the melting point of the brazing alloy.

A paste which has given successful results is made by mixing four parts by weight of borax to one of ferric-chloride in hydrochloric acid. This solution

is used to form a thin paste with zinc-chloride. It is essential that the surface to be brazed be free from dirt, scale and grease.

Case Hardening

S-LESS Steel and S-LESS Iron cannot be case hardened without losing their rustless and stainless characteristics.

Cold Working

S-LESS Steel and S-LESS Iron can both be cold rolled and cold drawn. In drawing the steel, however, frequent annealings are necessary and the operation is difficult. S-LESS Iron can be drawn more readily.

The cold working or distortion of the surface of S-LESS Steel reduces its resistance to rust and corrosion so that a heat treatment and grinding, or machining becomes necessary. *Every trace of scale or oxide must be removed from* S-LESS *Steel.*

S-LESS Iron after cold working requires no heat treatment to make it resistant to ordinary rusting conditions; however, its properties, including machinability, mechanical strength, resistance to erosion and corrosion can be improved by suitable heat treatment. *Every trace of scale or oxide must be removed from* S-LESS *Iron.*

Machining Properties

In the regularly annealed condition S-LESS Steel is readily machinable but for some purposes where very sharp angles or unusually smooth machined surfaces are required the Particularly Annealed Steel is recommended. Particularly Annealed Steel, however, is difficult to machine.

S-LESS Iron may be machined like ordinary wrought iron or soft steel.

Grinding

Aside from proper hardening *by far the most important process which influences stain-resistance is that of grinding.* It should be realized at the start that S-LESS Steel is more difficult to grind than ordinary steel. As has been mentioned S-LESS Steel conducts heat very slowly, hence great care should be used in grinding the hardened steel so that heat checks and "grinder's scorch" are not produced. "Grinder's scorch" is a yellowish-brown discoloration, due to improper grinding. Frictional heat is generated in local patches on the surface of the work and the resulting discoloration has every appearance of stain. This apparent stain is in reality a temper color but actual staining is quite likely to occur on surfaces where it is present. Wet grinding is always preferred. The grinding must be deep and thorough. Every trace of forging scale and surface oxidation must be removed. Any

remaining oxides or pits serve as seats for corrosion and an electrolytic action is set up which rapidly spreads over the surface of the material. A high polish can be obtained by dry finishing.

In the past it has been the belief of some that the surface stability of S-LESS Steel was due entirely to the degree to which the surface had been polished. On the contrary, the stain and rust-resisting properties are inherent in the steel, being the result of composition combined with heat treatment. A smooth, highly polished surface is to be desired in order that no pits shall offer "seats of corrosion" or spots where electrolytic action may start.

Etching

S-LESS Steel shows a remarkable resistance to the effect of nitric acid whether cold or boiling and in any degree of concentration. It is readily attacked by both hydrochloric and sulphuric but neither of these acids alone serve as a good etching medium. The following mixtures and solutions have been found to give satisfactory results:

1. Saturated solution of ferric-chloride in hydrochloric acid, to which a little nitric has been added. Use full strength.
2. For light etching. A saturated solution of copper-sulphate in hydrochloric acid.

3. For light etching.

   Hydrochloric acid .....100 parts
   Water .....100 parts
   Mercurous Nitrate ..... 7 parts

   Heat to effect complete solution but use cold.

4. Aqua Regia. ($3\ HCl + HNO_3$). The mixture of these two acids should be allowed to stand for 24 hours before using. It is used full strength for rapid work but requires very careful handling.

In general, the best results are secured where weaker solutions are used and a longer time allowed for etching.

Although in the manufacture of Stainless Steel it is the practice to strike a stencil mark into the red hot bar to indicate the type of steel, and although some foreign cutlery makers stamp the blades instead of etching them, experience has shown that unless all of the black scale, which is driven into the steel by stamping, is removed, corrosion may occur in the impression and spread to the polished part of a knife blade or other articles. We recommend etching as always preferable to hot stamping. Methods of Electric Etching are now being worked out.

Pickling

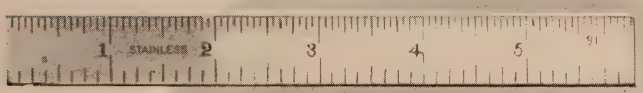
Stainless Steel is readily attacked by both Hydrochloric and Sulphuric Acids. A solution of either of these acids will be found suitable for a pickling medium, although the most satisfactory results will be obtained

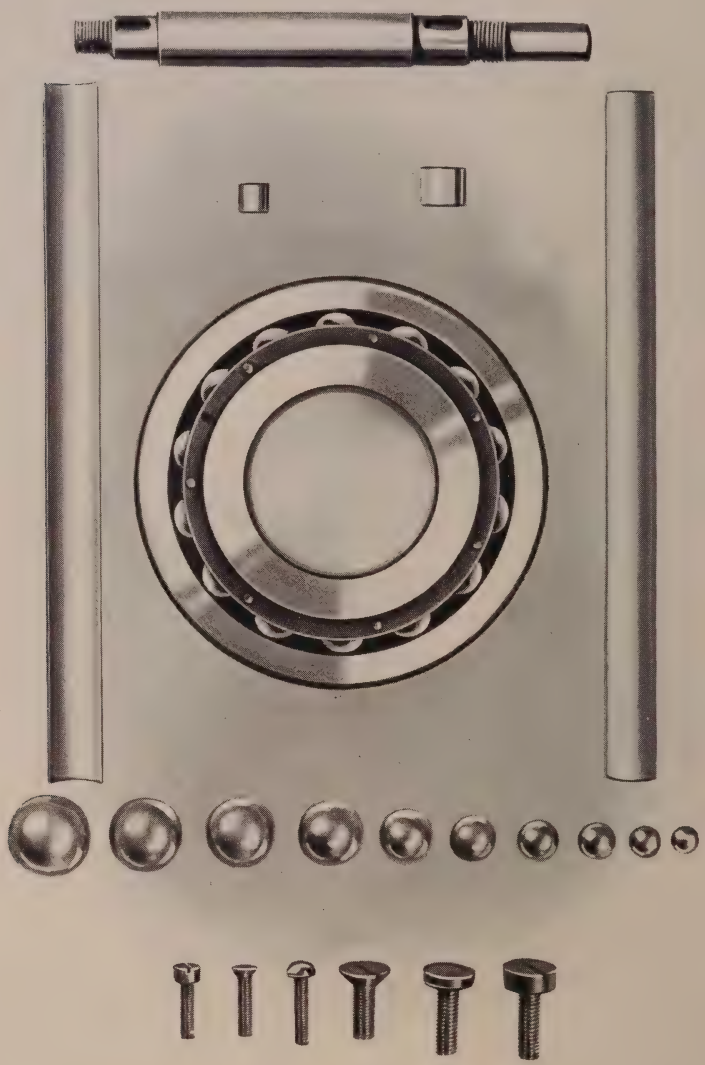
by the use of a 50% solution of Hydrochloric to which a little Nitric Acid has been added. A boiling solution of 20% Sulphuric Acid has been found to give fairly good results but extra precaution is necessary to prevent pitting.

Chemical Analysis

The various patents owned by the American Stainless Steel Company, from whom the Firth-Sterling Steel Company obtained its license to manufacture Stainless Steel, contain information on the subject of Chemical Analysis. A typical analysis of S-LESS Steel shows Carbon .30 and Chrome 13.00. S-LESS Iron analyzes about the same as S-LESS Steel excepting that the carbon runs about one-half that of the Steel.

Firth-Sterling S-LESS Stainless Steel, like all Firth-Sterling Brands, is sold on Brand and Performance, and not to Carbon Content or Chemical Analysis.





Physical Properties

Corrosion

Although S-LESS Steel is a steel of high tensile value and one which offers great resistance to heat oxidation and the softening effects which usually accompany high temperatures, its most remarkable property is its surface stability or its resistance to stain, corrosion and rust. The steel shows this exceptional property to a maximum degree when in a properly hardened condition and when a clean, smooth surface is exposed.

Tensile Properties

S-LESS Steel ranks high among steels noted for their high tensile strength, being a close competitor of the well known Chrome-Nickel and Chrome-Vanadium combinations. It is especially valuable on account of the wide drawing temperature range at which a 200,000 lb. per sq. in. breaking strength can be obtained. When properly hardened, little difference is noted in the tensile strength of the steel whether it is drawn at 500° F. or 950° F. When drawn below 500° F. lower values as regards reduction of area and elongation are obtained, while no advantage in tensile strength can be noted. Hardened S-LESS Steel drawn at 950° F. is non-staining but cannot be machined.

Below is given a table showing some of the physical properties when the steel is drawn at temperatures under 950° F.

200,000 LB. TENSILE STRENGTH CONDITION

Oil Quenched at 1825° *F. Drawn at* 575° — 950° *F.*

Yield point	170,000 — 210,000	lbs. per sq. in.
Tensile Strength	200,000 — 250,000	lbs. per sq. in.
Elongation	8.0% — 4.0%	
Reduction of Area	20.0% — 10.0%	
Brinell	400 — 475	
Scleroscope	60 — 70	

When drawn at temperatures in excess of 1050° F., a marked change in tensile properties takes place and much lower results are obtained. At still higher temperatures, 1200° F. to 1400° F., the drop takes place very rapidly and the steel becomes exceptionally tough. It might be well to mention at this time that there is an intermediate state which exists between the 225,000 lbs. and the 150,000 lbs. tensile strength condition, over which there is considerable controversy and which offers a wide field for extensive research work. This is illustrated on pages 29 and 30.

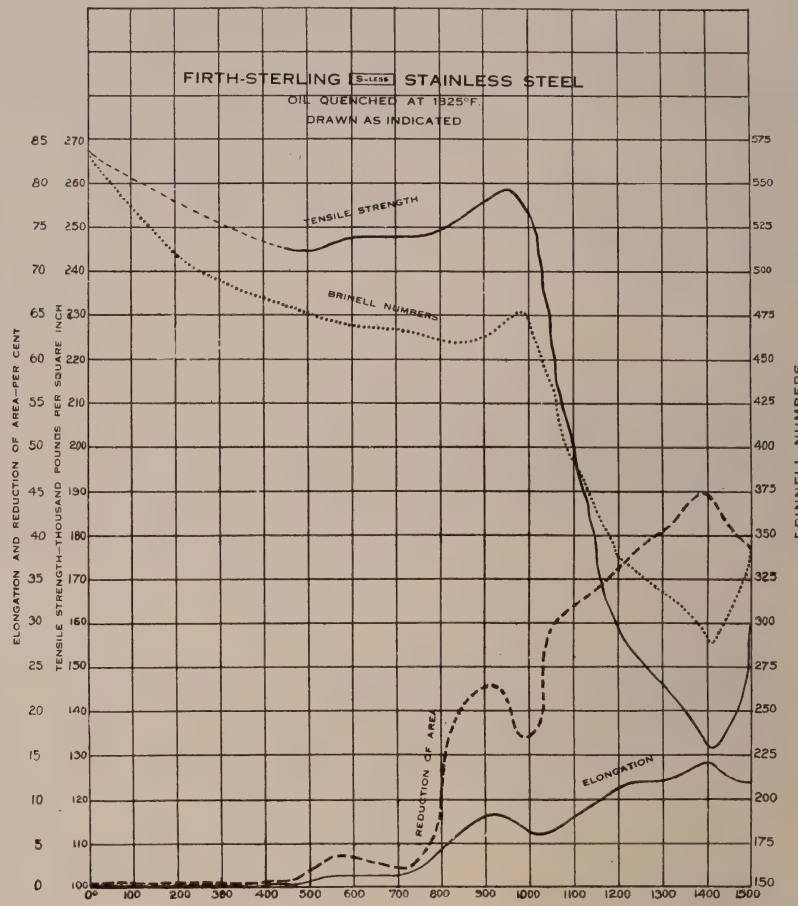
Tensile Properties of Stainless Steel

.30 C. 13.00 Cr.

Oil quenched at 1800° *F. Drawn as indicated.*

DRAWN AT	YIELD P. LBS. SQ. IN.	TEN. STR. LBS. SQ. IN.	ELONG. % IN 2"	R.A. %	BN. NO.	FRACTURE
950° F.	203,508	258,775	8.3	19.5	480	Flat
1000° F.	195,508	250,275	6.6	15.9	460	Flat
1050° F.	191,450	225,083	7.4	22.0	425	Flat
1100° F.	170,558	197,183	10.2	32.7	375	Starry
1150° F.	145,136	174,864	9.9	31.6	375	Starry
1200° F.	131,670	159,284	11.7	37.9	335	Starry
1250° F.	125,364	150,682	12.2	39.2	325	Starry
1300° F.	121,155	146,798	12.4	40.5	315	Starry
1350° F.	113,762	140,857	13.4	43.5	305	Starry
1400° F.	103,900	130,975	14.4	45.8	285	Starry
1450° F.	104,038	137,863	12.8	39.5	305	Cupped
1500° F.	114,138	159,975	12.4	34.0	340	Starry
Ann'd	65,000	99,950	27.0	58.7	175	Starry

The mechanical properties of the steel may be modified by raising or lowering the quenching heat. The lower heats give better mechanical properties but at some sacrifice to Hardness and Stain Resistance. One of the standard treatments is illustrated in the following graphic record.


FIRTH-STERLING S-LESS STAINLESS STEEL
OIL QUENCHED AT 1925°F.
DRAWN AS INDICATED
TENSILE STRENGTH
BRINELL NUMBERS
REDUCTION OF AREA
ELONGATION
ELONGATION AND REDUCTION OF AREA—PER CENT
TENSILE STRENGTH—THOUSAND POUNDS PER SQUARE INCH
BRINELL NUMBERS
85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100
575 550 525 500 475 450 425 400 375 350 325 300 275 250 225 200 175 150
0° 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500

TEMPERATURES DEGREES F.

The foregoing graphic chart was drawn from actual figures obtained under test conditions, with the exception of the tensile strength from 0° to 400° F. drawing temperatures.

Scaling at High Temperatures

As the temperature of ordinary steel rises the surface oxidizes into a scale of measurable thickness, and even at a low red heat the thickness of the scale increases with time. [S-LESS] Steel behaves quite differently.

Up to a temperature of about 1480° F. the gloss surface, due to polishing and hot tinting, is permanent and the specimen neither gains nor loses appreciably in weight. Its comparative value in this respect is illustrated by the following chart, which records the percentage loss in weight of various steels after exposure for many hours at temperatures above red heat.

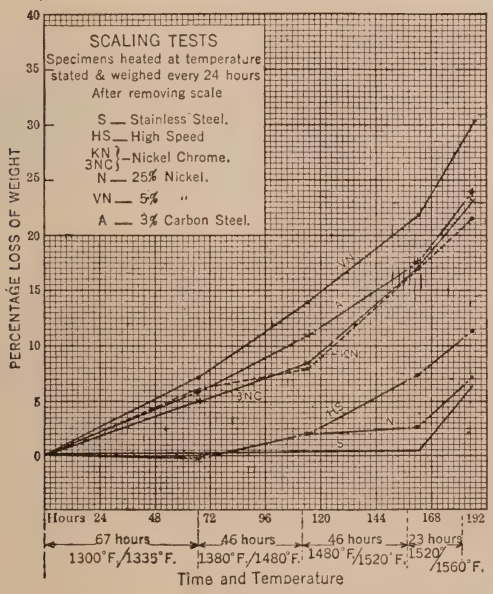


CHART ON SCALING TESTS

Properties at High Temperatures

S-LESS Steel retains its strength with increasing temperatures to a remarkable extent, being exceeded in this important property only by High Speed Steel, which is considerably more brittle at the elevated temperatures. This property makes the material especially valuable for poppet valves for internal combustion engines. For instance, a hardened piece "pulled" at a temperature of 930° F. will show a tensile strength of approximately 100 tons; at 1100° F. approximately 35 tons and at 1300° F. approximately 15 tons, with a corresponding increase in elongation.

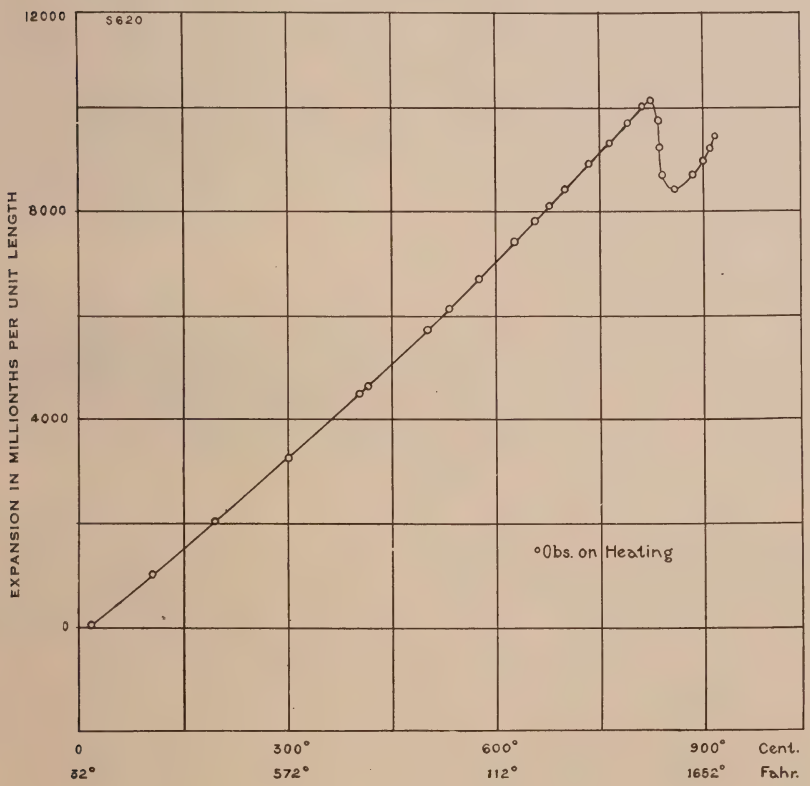
Coefficient of Expansion

The degree of expansibility of S-LESS Steel is of considerable importance when used in connection with internal combustion engine valves, steam fittings, etc. Although only slightly less in degree of expansion than ordinary steel, there is sufficient difference to be of considerable advantage. The coefficient of expansion of several of the most common materials as compared to S-LESS Steel is given below. These figures represent the linear expansion in fractions of an inch, per degree centigrade, at temperatures up to 200° C.

MATERIAL	COEFFICIENT OF EXPANSION
S-LESS Steel	.0000109
Mild Steel	.0000125
Copper	.0000172
Brass	.0000187

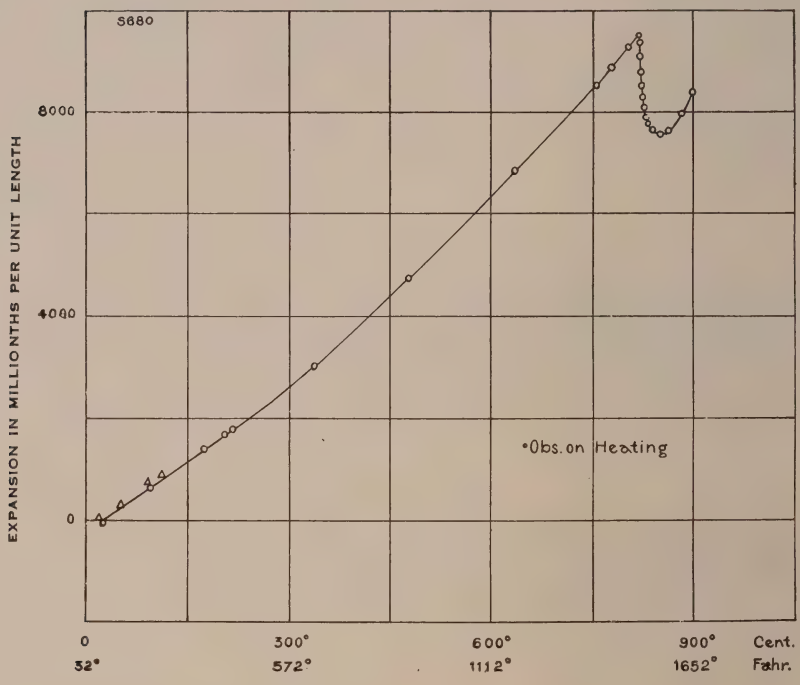
Coefficient of Linear Expansion

The following charts are taken from the Bureau of Standards Scientific Paper No. 426, pages 512 and 513. Firth-Sterling S-LESS Steel was used in these tests.



THERMAL EXPANSION OF ANNEALED STAINLESS STEEL

Coefficient of Linear Expansion—(Continued)



TEMPERATURE

THERMAL EXPANSION OF HARDENED STAINLESS STEEL

Modulus of Elasticity

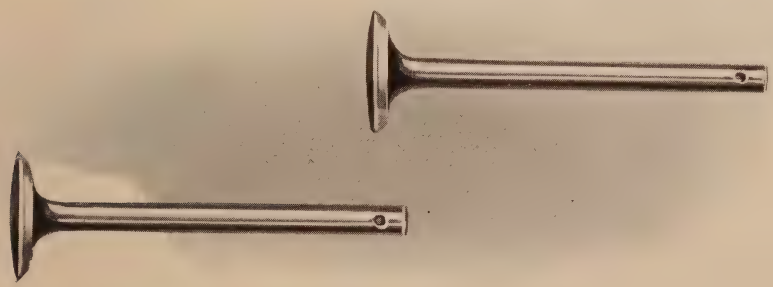
Experiments have shown that the modulus of elasticity of [S-LESS] Steel is slightly in excess of 30,000,000 lbs. per sq. in.

Thermal Conductivity

The rate of heat transmission has been determined on [S-LESS] Steel in both the hard and soft condition. In the hardened state, the conductivity is less than in the annealed condition, being only about three-fourths of the latter.

The thermal conductivity of pure iron is .146 c.g.s. units. By comparison with pure iron, [S-LESS] Steel in the soft condition has a thermal conductivity of .0445 c.g.s. units, being about one-third that of iron. Summarized, these figures show the following:

Soft [S-LESS] Steel	.0445 c.g.s. units
Hard [S-LESS] Steel	.0334 c.g.s. units
Pure Iron	.1460 c.g.s. units



Electrical Conductivity and Resistivity

The electrical specific resistance of [S-LESS] Steel in the soft condition is fifty to fifty-five microhms per centimeter. In the hardened and tempered condition its resistance is increased to sixty-five to seventy microhms per centimeter. For transmission purposes, it may be compared to pure iron which has a resistance of only one-sixth that of [S-LESS] Steel. The resistance of copper is one-seventh that of pure iron, so by comparison the resistance of the steel is about forty-two times as great as that of copper.

For wire to be used in heating units the resistance of the steel is only about half that of Nichrome. A comparative table of the approximate electrical resistance of three common substances follows:

MATERIAL	MICROHMS PER CM.
Copper	1
Pure Iron	8
[S-LESS] Steel	50
Nichrome	100

Magnetic Properties

Fairly good magnets can be made from [S-LESS] Steel. It is a splendid material for use where resistance to corrosion is required. In the soft state, it has the same degree of permeability as that of .90% carbon

steel in the normalized condition. Its best magnetic properties are brought out when it is hardened. Tests on samples of S-LESS Steel, oil quenched at a temperature of 1750° F., gave a coercive force of fifty-eight with a remanence of seventy-two hundred. Aside from its stain-resisting advantages, S-LESS Steel does not compare favorably with the Firth-Sterling "C" Magnet and Firth-Sterling Special Magnet Steels.

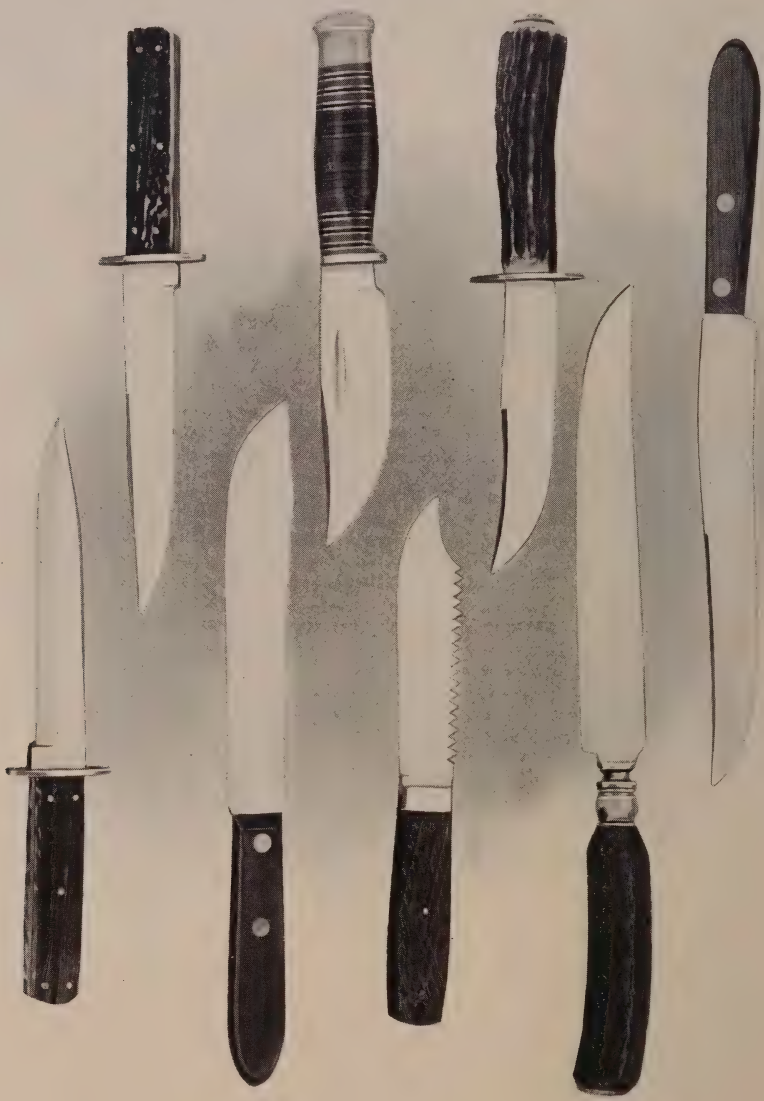
Specific Gravity

The specific gravity of S-LESS Steel is 7.75, being considerably less than that of Blue Chip High Speed Steel. A comparison between it, Blue Chip High Speed and Firth-Sterling Special Tool Steels, is as follows:

STEEL	SPECIFIC GRAVITY
Blue Chip High Speed Steel	8.50
Firth-Sterling Special Tool Steel	7.83
Firth-Sterling S-LESS Steel	7.75

Melting Point

The melting point of S-LESS Steel is higher than that of High Speed Steel. From observations taken during the melting of the steel and the pouring and solidification of it into ingots, the melting point has been found to be in the vicinity of 2750° F.

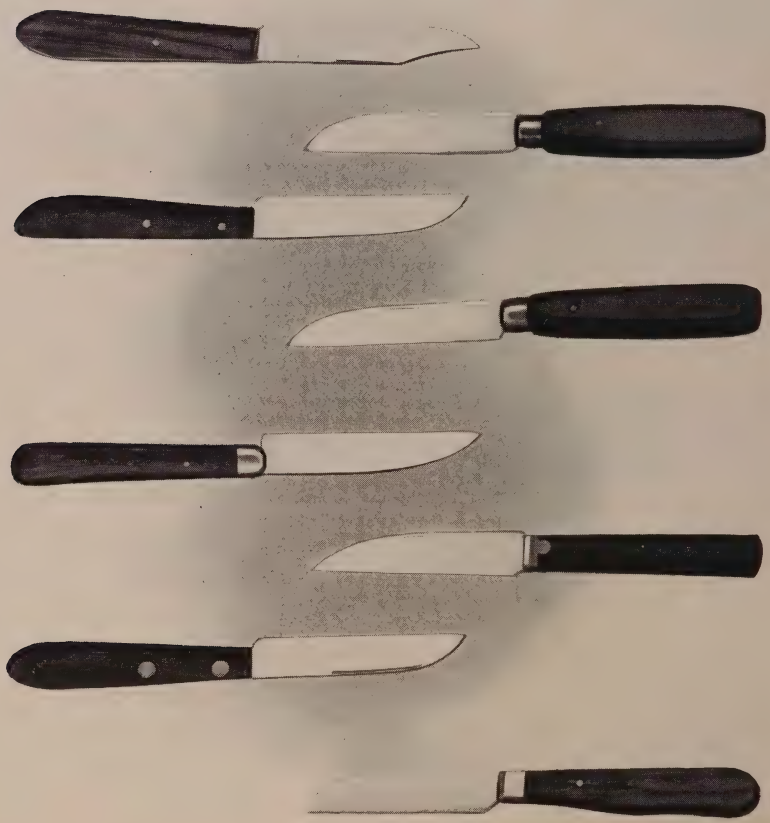


Cutting Properties

No claim is made for [S-LESS] Steel as a suitable steel for metal cutting tools. Its cutting field is limited to table cutlery, pocket knives, hunting knives, surgical instruments, meat cutting blades, leather knives, etc. For these purposes it serves admirably. Occasionally, knives made of [S-LESS] Steel are found which are not hard enough for table use. For years makers of cutlery have been accustomed to the working of steel which hardens at a red heat, about 1400° F. A heat approximating a lemon color, (about 1825° F.) is necessary to properly harden [S-LESS] Steel. It can readily be seen that the tendency is towards quenching at too low a heat and in our experience we have found this to be true. In exceptional cases, however, we have noted that the other extreme is sometimes reached. Knives have been examined which were soft yet brittle on the tip or point of the blade. These blades had no doubt been considerably overheated and burned. Many other factors, such as decarbonization of the cutting edge, improper grinding, and lack of uniform heating and quenching, have in the past given faulty results which have been wrongly attributed to the lack of hardening properties in the steel.

Ordinary steel knives stain and discolor readily, which necessitates frequent scouring or cleaning with an abrasive. This daily operation has a tendency to

keep the cutting edge sharp. S-LESS Steel knives are never scoured, but should be sharpened occasionally by means of a steel or sharpening machine to insure a keen cutting edge.



Resistance to Various Agencies of Rust, Stain and Corrosion

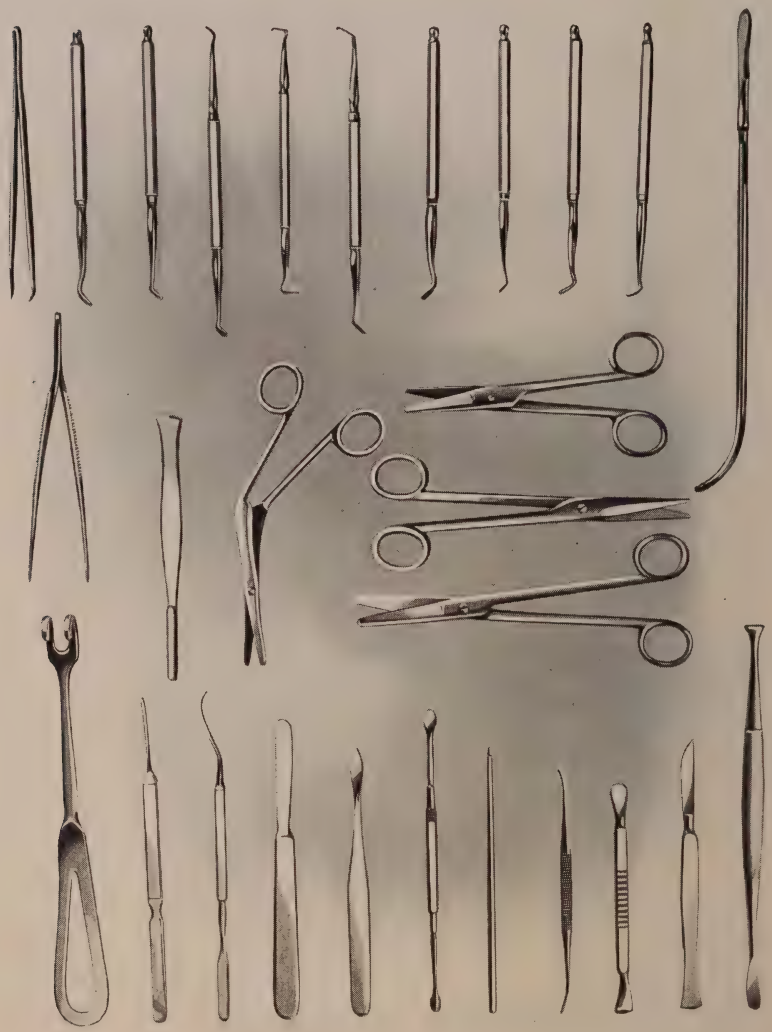
(when properly treated and finished)

Weathering

This is the most common of all corrosive influences, but has little or no effect upon [S-LESS] Steel and [S-LESS] Iron. Samples have been exposed to all types of weather, wet and dry, frost and snow, for many months and at the end of that time have been perfectly bright and unaffected in any way. Specimens placed in streams have retained their original brightness after months of exposure. Water containing a high percentage of dissolved oxygen has no appreciable effect upon [S-LESS] Steel or Iron. The atmosphere of industrial cities has a superficial effect, but this is due essentially to the products of combustion present in such localities. Oxides of sulphur are found in smoke and in the finely divided cinders which are precipitated from it. In connection with a moist atmosphere, such conditions offer quite severe tests to the stain resistance of [S-LESS] Steel and Iron.

Sea Water

When free from defects, the material is little affected by sea-water. The sea-water or brine solution test, however, is an excellent one for testing the perfection or degree of resistance.

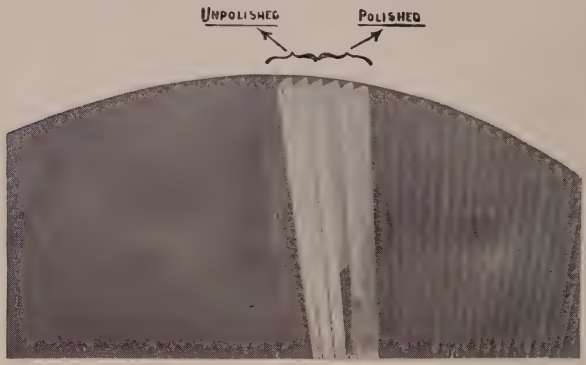


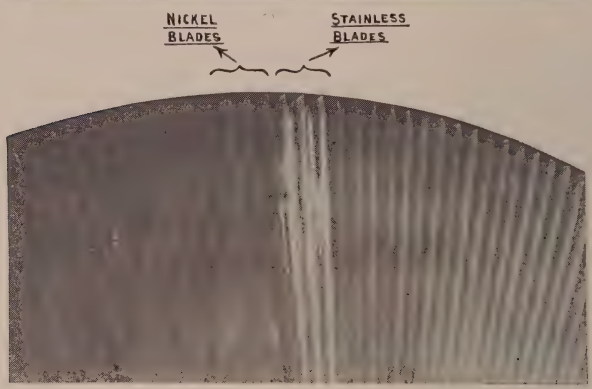
Metal Corrosion

Where two dissimilar metals are placed in contact in an electrolyte, a galvanic action is set up. This condition is very favorable to corrosion. [S-LESS] Steel is no exception to this rule. When it is used in a solution in connection with bearing metals, such as copper, bronze and brass, considerable tarnishing and pitting of the surface is noted.

Fruits, Vegetables, Meats and Vinegar

There is no doubt but that [S-LESS] Steel has made its reputation in the cutlery field. It is in this application, one of practical service, that it has clearly demonstrated its superiority over any other material heretofore offered. Millions of [S-LESS] Steel knives in use today have permanently established its value for this purpose. Fruit and vegetable acids, such as are present in the orange, lemon, apple, tomato, etc., show no effect whatever. Pickling vinegar offers a slight attack, due to the presence of hydrochloric acid formed during the reaction of the acetic acid upon the sodium chloride or salt usually found in pickling solutions. [S-LESS] Steel and Iron offer complete resistance to the effects of lye or ammonia. Thus it can readily be seen that their resistance to the above common corrosive agents, has made [S-LESS] Steel and Iron exceptionally efficient materials for all kinds of table cutlery and culinary utensils.


UNPOLISHED
POLISHED


NICKEL BLADES
STAINLESS BLADES

Mention has been made of the fact that S-LESS Steel shows its highest resistance to stain when in the hardened or some modification of the hardened state. This rule applies to all cases, whether the hardness be due to a high quenching temperature or the result of a low tempering heat. Within reasonable limits, in which composition plays an important part, the harder the steel, the more resistant the surface.

In the foregoing, mention has been made only of the application of S-LESS Steel to common household articles and of its resistance to tarnishing agents met with in everyday life. However, its use is not limited to this narrow field. It has a very wide field of application to which it readily adapts itself as shown by its behavior with the following corrosive reagents:—

Acetic Acid. Glacial Acetic has no effect. Diluted to various strengths it attacks slightly. It is a remarkable fact that vinegar which contains 5% Acetic acid, has little or no effect upon properly hardened and polished Stainless Steel.

Acetic Anhydride Acid. Attacks readily.

Acetone. Slightly attacks the steel.

Alcohol. The hardened steel is not appreciably attacked by ethyl alcohol or ordinary alcoholic beverages.

Alkalies. Caustic alkalies have no effect whatever upon the steel.

Alum. Strong solutions readily react upon the steel.

Aluminum Sulphate. Solutions of various strength attack the steel.

Ammonia. Solutions of ammonia have no effect.

Ammonium Chloride. Very marked corrosion.

Ammonium Sulphate. Steel is readily attacked.

Aqua Regia ($3HCl + HNO_3$). Stainless steel offers very little resistance to this combination of acids, regardless of whether the steel is hardened or annealed.

Baking Oven Gases. Very slight tarnish.

Benzene. No effect.

Benzol. No effect.

Blood. No corrosive action.

Boric Acid. The steel is unaffected by this acid in any degree of concentration.

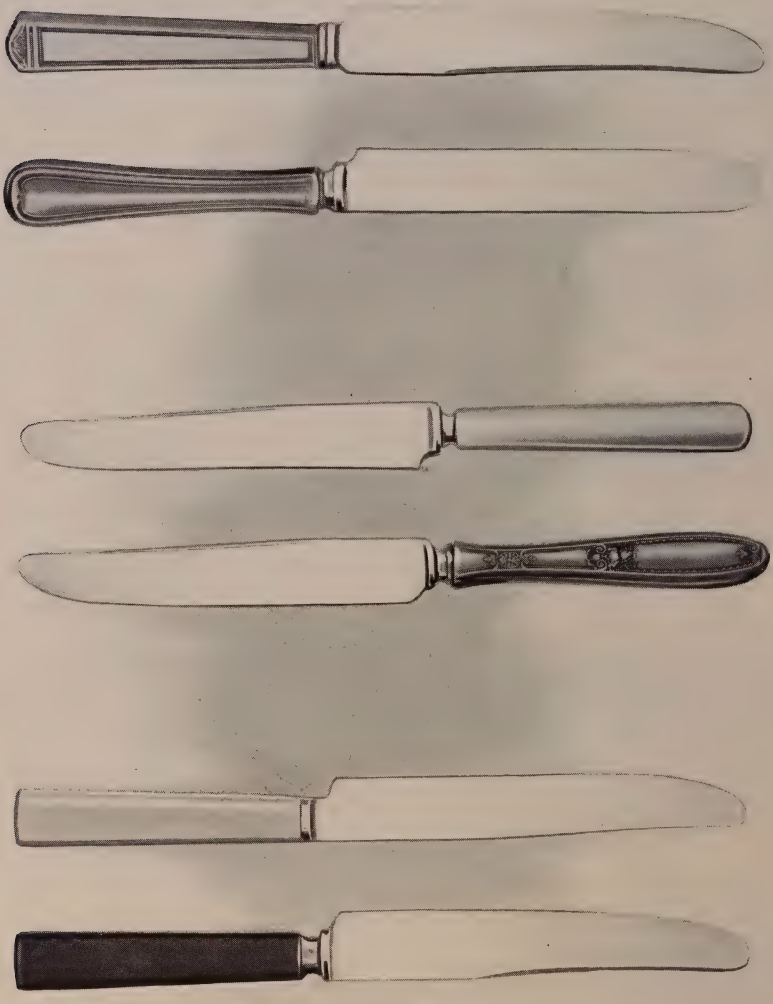
Calcium Chloride. Does not attack the steel in a saturated solution but dilute solutions have a slight effect.

Carbon Tetrachloride. Like many corrosive agents, the pure liquid has no effect but dilute alcoholic solutions readily attack the steel.

Chloracetic Acid. Attacks the steel in all conditions.

Chlorine. Either dry or moist chlorine gas readily attacks the steel.

Chlorosulphonic Acid. Immersed specimens not visibly affected but acid reacts on steel with moist



air and specimens partially immersed are attacked at level of the liquid.

Citric Acid. The steel is corroded in proportion to the strength of the acid. Lemon juice containing about 6% Citric Acid has no effect.

Copper Chloride. Readily attacks the steel.

Copper Sulphate. In a neutral solution, this salt does not appreciably affect the hardened steel.

Dry Battery Compound (A mixture of zinc and ammonium chloride with manganese dioxide). Very marked corrosion takes place.

Ferric Chloride. Readily attacks.

Formic Acid. The steel is attacked to a limited degree.

Gasoline. No effect.

Glue. Not ordinarily effected.

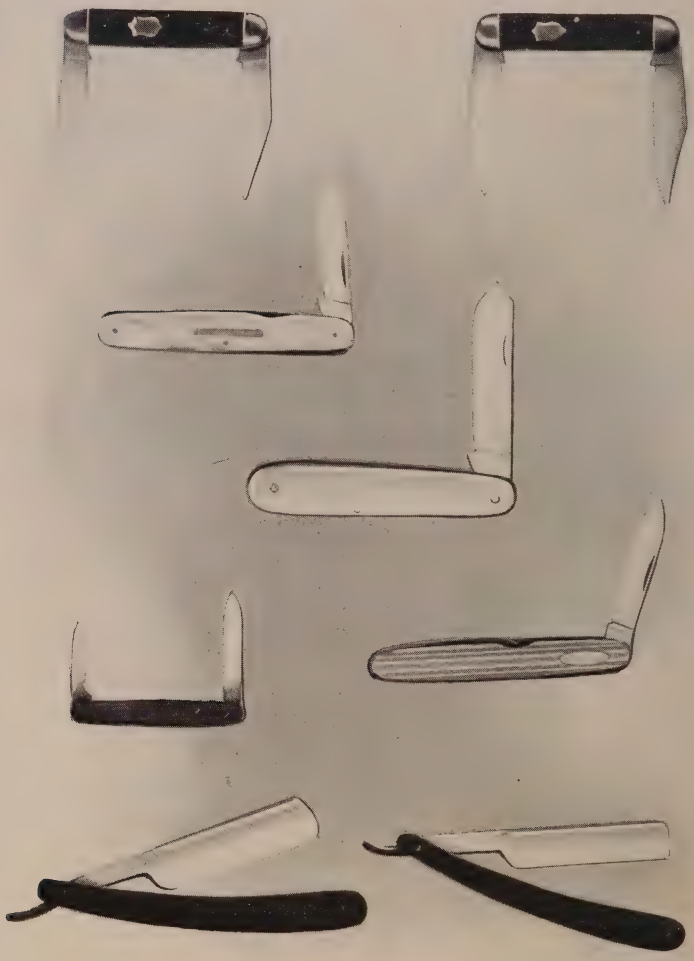
Hydrochloric Acid. Stainless Steel offers little resistance to this acid.

Ink. Stainless Steel has been tested with various makes and colors of ink. Little effect has been noted, although in some cases the steel was stained slightly.

Iodine. Corrodes but to a limited degree.

Lactic Acid. Corrodes to a considerable degree. Sour milk, although high in Lactic acid content, does not attack the steel.

Lemon Juice. No effect but steel is affected by Citric Acid (See notes on vinegar and acetic acid).



Lime. No effect whatever upon the steel.

Lysol. No effect upon the steel.

Magnesium Carbonate. A thick paste of this material was allowed to dry on the steel. No effect was noted.

Menthol. Strong alcoholic solutions stain the steel in proportion to the degree of concentration.

Mercuric Chloride. A marked corrosion takes place when strong solutions are used. Very dilute solutions, such as are used for surgical antiseptics, have little effect.

Mercury. No attack whatever.

Milk. Neither sweet nor sour milk affects the steel. See Lactic Acid.

Monochloracetic Acid. Attacks readily.

Nitric Acid. Practically no effect upon the steel. Boiling solutions of either dilute or concentrated acid do not attack it.

Novocaine. To note its adaptability for hypodermic needles, the steel was immersed in a 1% solution of this substance for seven days. No appreciable effect was disclosed.

Oils. Light or heavy lubricating oils, cylinder and paraffin oils have no effect.

Oleic Acid. No effect upon the steel.

Phosphoric Acid. A saturated solution has no effect. In various degrees of concentration, a slight general attack takes place.

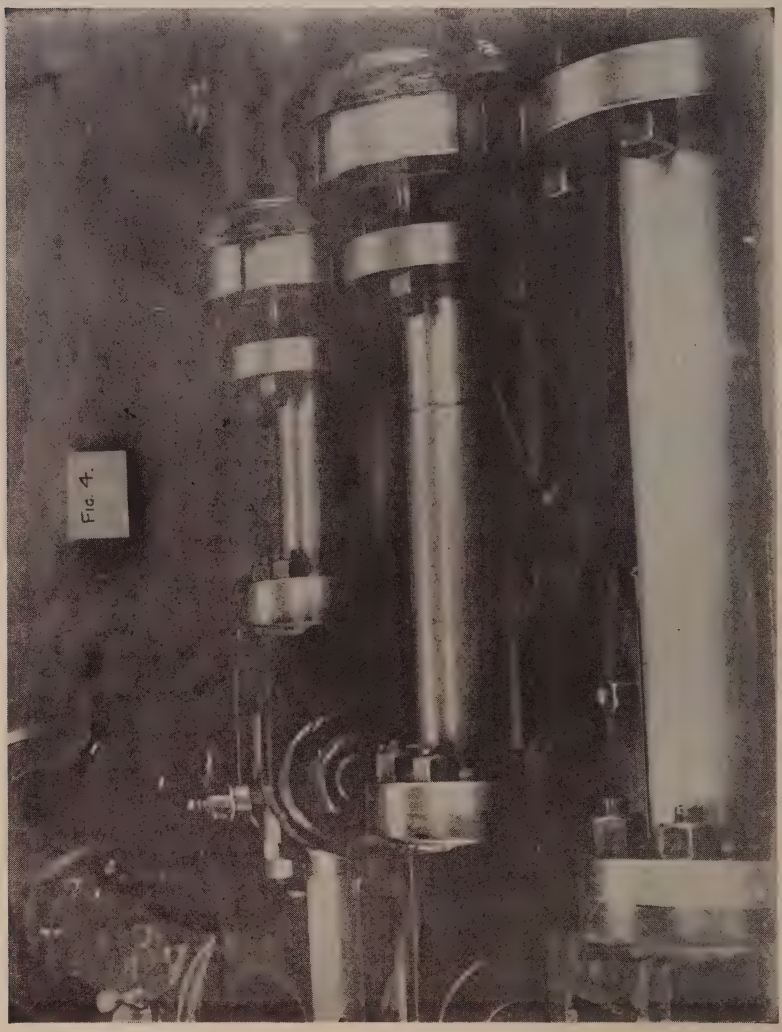


Fig. 4.

Potassium Cyanide. No effect on the steel.

Potassium Ferricyanide. Readily attacks the steel.

Potassium Oxalate. No effect on the steel.

Quinine Sulphate. Steel is noticeably pitted.

Quinine Bisulphate. Steel is noticeably pitted.

Rubber. Investigations made with apparatus meeting conditions in the vulcanizing of rubber indicate the steel is attacked due to Sulphur Chloride present.

Silver Bromide. No attack offered by this salt.

Sodium Chloride. Pitted locally by saturated solution (pure).

Sodium Salicylate. No noticeable effect.

Sodium Sulphate. Strong solutions of this salt readily attack the steel.

Soft Soap. Has no effect upon the steel.

Steam. No corrosion offered unless considerable amounts of some salt or acid is in solution in the water.

Stearic Acid. No effect upon the steel.

Sugar. Totally unaffected by any strength of solution.

Sulphur Chloride. In the presence of water or moisture, the steel is readily attacked by this corrosive chemical.

Sulphuric Acid. Readily attacks in any degree of concentration.

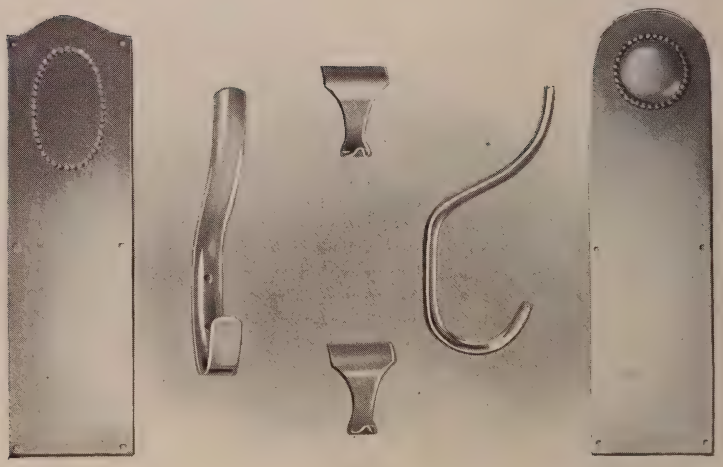
Sulphurous Acid. Very similar in its reactions to sulphuric.

Tannic Acid. Does not offer any attack but fumes cause a very slight stain.

Tannin. Practically no effect.

Thymol. Slightly stained by strong solutions.

Trichloracetic Acid. Attacks immediately and action is very rapid.



TERMS OF WARRANTY

We will replace any steel which proves defective when properly worked and treated and used for the purpose specified in the order, but no claim for labor or damages will be allowed. We cannot guarantee resistance to corrosion unless we know the exact conditions under which steel is to be used.

Index

	Page
Acetic Acid	45
Acetone	45
Acetylene welding and cutting	20
Air hardening property	15
Alcohol	45
Alkalies	45
Alum	45
Aluminum Sulphate	47
American Stainless Steel Company	9
Ammonia	43, 47
Ammonium Chloride	47, 49
Analysis	25
Annealing	13, 16
Annealed, Particularly	13
Applications	11, 12
Aqua Regia	47
Atmospheric corrosion	41
Battery Compounds	49
Benzene	47
Benzol	47
Blue Chip High Speed Steel	37
Boric Acid	47
Brazing	20
Brearley, Harry	9
Brinell hardness	16, 18, 28, 29, 30
Bureau of Standards Tables	18, 33, 34
Calcium Chloride	47
Carbon Tetrachloride	47
Case Hardening	21
Caustics	45
Chemical Analysis	25
Chlorine	47
Chloracetic Acid	47
Chlorosulphonic Acid	47
Chromium	9, 25, 27
Citric Acid	49
Coefficient of Expansion	32, 33, 34

	Page
Cold Working	21
Copper Chloride	49
Copper Sulphate	23, 49
Corrosion	27
Corrosion, Atmospheric	41
Corrosion, Metal	43
Corrosion, Seats of	23
Cutlery	11, 39
Cutting Properties	39
Deep Drawing	21
Discoloration at High Temperatures	18, 19
Drawing the Temper	18
Dry Battery Compound	49
Dry Finishing	23
Electrical Conductivity	36
Electrical Resistivity	36
Electrolytic action	14, 23, 43
Etching	23
Expansion, Coefficient of	32, 33, 34
Ferric Chloride	20, 23, 49
Finishing	13, 14, 21, 22, 23
Firth-Sterling Magnet Steel	37
Firth-Sterling Special Tool Steel	37
Firth & Sons, Ltd., Thos.	9, 10
Flux for brazing	20
Forging S-LESS Iron	19
Forging S-LESS Steel	15
Formic Acid	49
Fruits	43
Galvanic, see Electrolytic Action	
Gasoline	49
Glue	49
"Grinder's Scorch"	22
Grinding	22
Guarantee	55
Hardening treatment	17
Hardness	15, 16
Hardness of Cutlery	39
Heat Curves	18
Heat Treatment	14, 17

	Page
High Speed Steel	31, 32, 37, 39
History	9
Hot Stamping	24
Hydrochloric Acid	23, 24, 49
Identification Marks	23, 24
Ink	49
Iodine	49
Lactic Acid	49
Lemon Juice	49
Lime	51
Lye	43
Lysol	51
Machinability	13
Machining Properties	22
Magnesium Carbonate	51
Magnetic Properties	37
Meats	43
Melting Point	39
Menthol	51
Mercury	51
Mercuric Chloride	51
Metal Corrosion	43
Milk	51
Modulus of Elasticity	35
Monochloracetic Acid	51
Nitric Acid	51
Normalizing	16
Novocaine	51
Oils	51
Oleic Acid	51
Oven Gases	47
Oxidation, see Corrosion	
Oxide of Sulphur	41
Particularly Annealed	13, 14
Patents	9
Permanent Magnets	37
Physical Properties	14, 27
Phosphoric Acid	51
Pickling	24
Pickling Vinegar	43

	Page
Polishing	13, 22, 23, 27
Purposes	11
Possibilities	11
Potassium Cyanide	53
Potassium Oxalate	53
Properties at High Temperatures	32
Quinine Sulphate	53
Reduction Area	27, 28, 29, 30
Removal of Surface	13, 14, 21, 22, 27
Resistance to Heat	31
Rubber	53
Rust, see Corrosion	
Scaling at High Temperatures	31
Scale in Stencil Marks	24
Scorch, Grinders	22
Seats of Corrosion	23
Sea Water	41
Silver Bromide	53
S-LESS Iron	14
Smoke	41
Sodium Chloride	53
Sodium Salicylate	53
Sodium Sulphate	53
Soft Soap	53
Soldering	20
Solutions for Etching	23
Solution for Pickling	24
Specific Gravity	37
Stainless Iron Discovery	10
Steam	53
Stearic Acid	53
Stencil Marks	24
Sugar	53
Sulphur Chloride	53
Sulphuric Acid	53
Sulphurous Acid	54
Surface, removal of	13, 14, 21, 22, 27
Tannic Acid	54
Tannin	54
Temper Colors	19

	Page
Tempering	18
Tensile Strength	13, 14, 27
Terms of Warranty	55
Thermal Conductivity	35
Thymol	54
Trichloracetic Acid	54
Types of Stainless Steel	13
Uses	11, 12
Vegetables	43
Vinegar	43
Warranty	55
Weathering	41
Welding	20
Wet Finishing	22
Yield Point	27, 28, 29
Zinc Chloride	21

GETTY RESEARCH INSTITUTE
3 3125 01093 3485